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FINAL REPORT

Title: Persistence of Diflubenzuron (Dimilin) in a Small Eastern Watershed and its Impact on Invertebrates in a Headwater Stream.

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Persistence of Diflubenzuron (Dimilin) in a Small Eastern Watershed and its Impact on Invertebrates in a Headwater Stream

SUMMARY

Diflubenzuron, a chitin inhibitor, is frequently the pesticide chosen for gypsy moth control because of low application costs and selectivity of action. The persistence of Dimilin following aerial application is relevant to efficacy as well as to hazards associated with its use in gypsy moth suppression operations.

The persistence of Dimilin in water and vegetation from forestry uses has been identified as a data gap in the development of Environmental Assessments, and questions have been raised concerning the potential for adverse effects on aquatic invertebrates.

Following aerial application at 0.06 lb a.i. per acre to a 75 acre watershed containing a small, first-order stream, persistence of Dimilin was measured in stream-flow, sediment, forest floor and through-fall precipitation through time post-spray. The impact of Dimilin on aquatic invertebrates in the treated stream was determined by comparing populations following the application with previous populations in the same stream, and populations in a nearby control stream.

Concerns such as those mentioned above, raised during the "scoping" process for a gypsy moth eradication operation on the Tusquitee RD of the Nantahala National Forest, prompted the spray operation directors to initiate a monitoring program as a part of the operation. Those data are included in this report.

It was found that Dimilin reached the stream channel during aerial application and as a result of wash-off from the foliage for several subsequent rainfall events. Levels were measured which exceed the acute (1.0-1.8 PPB) and chronic (60 PPT) toxicity doses for intolerant taxa such as Ephemeroptera and Plecoptera. However, the residence time for Dimilin in these high-gradient streams was very short. The data on invertebrate populations indicate that either as a result of short residence time or low concentrations, toxic effects were not evident.

Persistence of Diflubenzuron (Dimilin) in a Small Eastern Watershed and its Impact on Invertebrates in a Headwater Stream

Introduction:

Dimilin, a chitin inhibitor, is frequently the insecticide chosen for gypsy moth control due to low application costs and selectivity of action. The persistence of Dimilin following application is relevant to hazards associated with its use in gypsy moth control operations.

In some early studies of Dimilin for mosquito control, using application rates similar to those used for gypsy moth, Schaefer and Dupras (1976, 1977) concluded that it was not persistent in soil and water, although they reported some build-up of the wettable powder formulation on vegetation following multiple applications. However, in studies on cotton (Bull and Ivie 1978), Dimilin was found to be very persistent through 9 months in soil. They also reported that it persisted as a surface deposit on foliage and was subject to wash-off in heavy rain. Ivie et al. (1980) studied the effect of temperature and pH on the fate of Dimilin in water. They reported that degradation was highly dependent upon pH, with a half-life of less than 3 days at pH 10, about 7 days at pH 6, and no detectable degradation through 56 days at pH 4.

In a study of environmental impacts of Dimilin (Willcox and Coffey 1978), it was concluded that spraying with Dimilin at 0.06 lb/ac had no adverse effect on the macrobenthic community in the test stream. However, in studies with complex laboratory streams, Hansen and Garton (1982) reported that five months of continuous exposure to 1.0 PPB or more of Dimilin resulted in severe direct toxic effects to some groups of aquatic invertebrates. They found large reductions in populations of stream herbivores and leaf shredders, which resulted indirectly in increases in algal and fungal biomass in the streams.

The persistence of Dimilin in water and vegetation from forestry uses has been identified as a data gap in the development of Environmental Assessments. The availability of small instrumented watersheds in the Fernow Experimental Forest in Parsons, West Virginia provided the opportunity to gather data on the persistence of Dimilin in water, sediment and forest floor (litter) following a spray operation such as those conducted for gypsy moth suppression.

The potential for adverse effects on aquatic invertebrates has also been identified as one of the environmental risks of Dimilin use for gypsy moth control practices. It was considered possible that small headwater streams, which are subject to receiving direct and indirect imput of Dimilin from gypsy moth suppression operations, and which do not have the potential for recolonization by aquatic invertebrates from untreated areas upstream, might suffer severe and long-term changes in aquatic macroinvertebrate community structure. The existence of background data on invertebrate populations through time in the experimental watersheds allowed us to compare the invertebrate populations in the treated stream with previous populations in the same stream, as well as those in a nearby control watershed.

Concerns about adverse effects raised during the "scoping" process for a gypsy moth eradication operation in the Fires Creek watershed on the Tusquitee RD of the Nantahala National Forest prompted the operation directors to initiate a monitoring program as a part of the operation.

That data will be included in this report.

Objectives:

(1) To determine the persistence of Dimilin in water, sediment, and the forest floor following aerial application;

(2) To determine the impact of spraying a whole watershed on invertebrate populations in a small headwater stream.

Methods:

This research was conducted on the Fernow Experimental Forest, in the Allegheny mountain region, near Parsons in north-central West Virginia. The treatment watershed (Watershed 1) is an east-facing watershed of 75 acres with an average slope of 40 percent. Elevation ranges from 2,100 to 2,800 feet. It supports a dense stand of hardwood sprouts and seedlings, natural reproduction after clearcutting in 1958. Predominant species include oaks, maples, beech, yellow-poplar, basswood, and black cherry. The soil, Calvin channery silt loam, is derived from sandstone and acid shale. Soil depth ranges from 2 to 5 feet, with an average depth of 32 inches. Precipitation (average 58 inches/year) on the forest is sampled with a 19-gauge network. Streamflow (average 23 inches/year) is recorded continuously using 120° V-notch weirs. The nearby 96 acre control watershed (Watershed 4) is similar in all respects except its tree cover, which is mature and undisturbed hardwood.

Dimilin was applied by fixed-wing aircraft (AgCat) at the rate of 0.06 lbs active ingredient in 1.0 gallon per acre total mix.

Duplicate 400 ml water samples were taken at hourly intervals for the first seven days, using ISCO automatic samplers, and at selected intervals thereafter. Five base-load sediment samples were taken from the weir pond at 2 hours, 1 week, and 1 month post-spray. Ten subplots for litter and through-fall precipitation were randomly chosen along a transect through the watershed. Litter samples were taken at 1 hour, 1 week, 1 month, and 5 months. Leaf fall from the spray plot was collected in nets above the forest floor. Through-fall precipitation was collected for the first six rainfall events post-spray. Pre-spray samples of all compartments (water, sediment, and litter were included in the residue analysis to establish baseline analytical data. Glass petri dishes placed along the stream channel provided a quantitative measure of the amount of Dimilin reaching the stream during the spray operation.

Residue monitoring in the Fires Creek eradication operation was based on this strategy, with petri dishes along the stream channels supplemented with Kromkote cards for immediate visual evaluation of Dimilin levels reaching the streams. Water samples were collected from two small tributaries over-sprayed with Dimilin, and from the larger Fires Creek itself, for 12 hours. One ISCO sampler was set to activate with a rise in streamflow associated with rainfall events, and provided direct data on Dimilin washed into the stream by a rain which occurred 2 days after the second Dimilin application (9 days after the first application) to one monitored tributary.

Residue Analysis:

Water samples were returned to the laboratory for processing at the end of each 24 hour collection. Samples were loaded onto prewashed

octadecyl (C-18) cartridges topped with 0.45 micron filters by vacuum aspiration through a length of 5 mm I.D. NALGENE tubing inserted into the sample bottle, and were stored at ambient temperature in the original foil-lined envelopes. Sample volumes were determined by weighing each sample bottle before and after sample loading. Dimilin is stable for at least 2 years on these cartridges, with a recovery of 99% (Jones, unpublished). Prior to High Performance Liquid Chromatographic (HPLC) analysis, a partial sample clean-up was accomplished by washing each cartridge with 30 ml of 30% acetonitrile in HPLC grade water. Dimilin was then eluted in 2 ml of 60% acetonitrile in water, resulting in a 200-fold sample concentration. HPLC analysis was accomplished by reverse-phase chromatography on a 3.9 mm X 30 cm octadecyl (C-18) column and UV detection at 280 nm wavelength and 0.02 AUFS, with solvent program of 7 minutes at 60% acetonitrile, then 100% acetonitrile at a flow rate of 1.0 ml/min. Quantitation was based on a comparison of peak area with a standard curve.

Sediment and litter samples were frozen prior to storage and HPLC analysis. Sediment samples were air-dried and sieved to remove large particles. 25 g subsamples of sediment were extracted by leaching overnight with 50 ml acetonitrile. Extracts were vacuum filtered through Buchner funnels, diluted to 1,000 ml with HPLC grade water, and loaded onto C-18 cartridges for clean-up and concentration as described above for the water samples. The frozen litter samples were crushed, and a 2g subsample was extracted by leaching 24 hrs with 50 ml of acetone. The extracts were vacuum filtered through Buchner funnels, and evaporated to dryness under a stream of air. The residue was dissolved in 100 ml of hexane and loaded onto Silica cartridges for clean-up and concentration, which was accomplished by serial elution with 90/10 (v/v) hexane/acetone. The cartridges were first eluted with 3 ml of the hexane/acetone to effect a partial clean-up; then the Dimilin was eluted with 10 ml of the solvent mix. The HPLC analysis for the sediment and litter used the same column and detector settings as previously described for the water analysis, with a solvent program of 10 min. at 50 % acetonitrile, followed by 100 % acetonitrile.

Invertebrate Sampling

Invertebrate populations in the treatment and control streams were measured by collecting three kick-net samples per stream in March and May, 1986, prior to the spray, and in June, July, October, 1986, and March, 1987, following the spray. In addition, six Hester-Dendee Multiple Plate samplers were placed in each stream for retrieval 6 weeks post-spray, and Rock-Basket samplers were placed in each stream for two 6-week intervals following the spray. All samples were immediately returned to the laboratory, preserved, and sorted. Taxa were identified to genus when possible, and numbers of individuals were recorded for each taxon. Taxa richness values over time were determined, as were measures of community similarity for treatment and control streams (Johnson and Brinkhurst 1971).

Results:

Residues:

The minimum detectable levels of Dimilin were 25 parts-per-trillion (PPT), 2.0 parts-per-billion (PPB), and 500 PPB, respectively, for water,

sediment and litter. These differences in sensitivity result from levels of interference associated with co-extractives from the various matrices. Average percent recovery from spiked samples of water was 99.6 %, 78 % for spiked sediment, and 104 % for spiked litter.

The data from the petri dishes in the Parsons study and the Fires Creek operation are shown in Table I. The amount of Dimilin reaching the stream channel during the spray operation is related to the extent of canopy closure, and probably to the spray path relative to the stream location in the watershed. In Parsons and on Bob's Branch in Fires Creek, the flight path was parallel to the stream, whereas in the larger Leatherwood Branch watershed, the spray was applied in multiple passes across the stream channel. The amounts measured in the petri dishes ranged from less than 1.0 % of the theoretical applied rate under heavy cover such as the Rhododendron characteristic of parts of the Fires Creek watershed, to as much as 52 % in a large open area such as the wildlife opening in Leatherwood Branch. It should be noted that the term "open canopy" refers to the most open areas we could find along the stream channels. In fact, because all of the watersheds met the Dimilin label requirements of no open water, there was some level of canopy over most sites. On-site visual inspection of the Kromkote cards suggested that less than 20 % of the applied rate was reaching the stream channel. Later analysis of Kromkote cards by the method used to calibrate the sprayer gave numbers consistently lower than the petri dish data.

The levels of Dimilin detected in the stream following the spray of Watershed I in the Fernow are depicted in Figure I. The first post-spray sample, drawn approximately 1 hour after the spraying was begun, showed 112 PPT in the stream. A heavy rain which began about 45 min. post-spray produced a spike of 2.1 PPB, contained in a grab sample collected manually at the time of peak streamflow from the storm. However, by the next scheduled sampling time, the level of Dimilin had returned to 126 PPT. Levels declined thereafter, reaching detection limits after 6 hours. A small spike (34 PPT) was detected in samples collected during the rainfall event which occurred on day 2, but a heavy storm on day 7 failed to wash detectable levels into the stream. It is apparent that in small, high gradient streams such as this, Dimilin levels are very transient.

Figure II depicts the average concentration (PPB) of Dimilin measured in the 10 throughfall precipitation samplers along with the rainfall measured at the rain gauge at the watershed for the six sampled rainfall events in the Parsons study, covering a total of 18 days post-spray. It was shown that measurable amounts of Dimilin were washed off the foliage for 16 days post-spray. These data, which seemed to conflict with the suggestion that as little as one hour for the spray deposit to dry on the foliage eliminated problems of wash-off, prompted us to sample precipitation and stormflow in our monitoring at Fires Creek, in order to substantiate these data or to determine if they were an anomaly associated with the fact that the Parsons spray had been subjected to rain immediately post-spray.

For the Fires Creek eradication project, ISCO samplers were installed in two tributaries in the Dimilin spray block, and in Fires Creek below the confluence of each of these tributaries. In the larger tributary, Leatherwood Branch, 61.4 PPT was detected in one replicate, and a trace (>25 PPT) in the other replicate, at one hour post-spray. No Dimilin was detected thereafter for the 12 hour sampling time. A trace was detected

in the two hour sample in the second tributary, Wolfpen Branch, and no Dimilin was found at any time in Fires Creek itself.

Figure III depicts Dimilin levels found in throughfall precipitation and stormflow in Leatherwood Branch. The only measurable rainfall during the monitoring period occurred two days after the second application to Leatherwood Branch (9 days after the first). Analysis of the five throughfall samples yielded an average of 2.56 PPB from 0.61 in rainfall. A peak of 406 PPT Dimilin was found in the stream during the second hour of elevated flow, with levels declining to just above detection limits (48 PPT) after six hours, when the sampler shut off as the stream level returned to normal. These data demonstrate that wash-off of the spray deposit, even after 2 days, introduced more Dimilin into the stream than the spray application by a factor of almost 10. Here again, as in the experimental spray at Parsons, the Dimilin was flushed from the stream quite rapidly.

Table II lists residue data from sediment and litter samples from Parsons. From 2 to 10 PPB was found in the sediment of the weir pool one hour post-spray, but had declined to below detection limits by one week. Dimilin levels were variable in the litter collected from around the watershed. The apparent trend was toward increasing levels in the litter from the first to last sampling date. We can only speculate that wash-off from the sprayed foliage was introducing Dimilin faster than it was degrading on the forest floor. Leaf-fall in October was collected in nets suspended above the forest floor, and analysis revealed no detectable residues on the new leaves reaching the forest floor; however, it precluded meaningful continuation of the litter sampling. Obviously we were not able to measure rate of decline of litter residues.

Invertebrate Sampling:

The invertebrate populations of the two watersheds in the Fernow were sampled in May, 1983 (Case unpublished), and in April, 1984. We then collected samples in March and May, 1986, prior to the spray, and in June, July, and October, 1986, and March, 1987, after the spray. Table III lists the total taxa collected at each sampling date, and taxa richness values for Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). These three groups of aquatic invertebrates are typically dominant members of the aquatic community in small, clean mountain streams, where the principal source of nutrients is allochthonous material such as leaves and other detritus from the forested areas which they drain (Vannote et al. 1980). They are also intolerant of water quality disturbances (Hilsenhoff 1982), sensitive to insecticides (Hanson and Garton 1982), and at risk because they are leaf shredders, collector/gatherers, and filter feeders (Merritt and Cummins 1978). These feeding strategies might bring them into direct contact with an insecticide applied to forest foliage. Comparison of the EPT richness values for the treatment and control streams over time indicate that these sensitive taxa have not been adversely affected by this application of Dimilin. Table IV shows community similarity comparisons within each stream at various sampling times. CC (Coefficient of Community) is a simple measure of the similarity of the community structure of two samples, calculated at the genus level for EPT taxa only, and PS_C (Percent Similarity Coefficient) weights the calculation for abundance of

individual genera in the sample (Johnson and Brinkhurst 1971). According to Johnson and Brinkhurst, CC values of 50 or more and PS_C values of 30 or more are indicative of high similarity between two communities. The within stream comparisons for both watersheds exceed these values for all dates, including those which compare pre- and post-spray populations in Watershed 1, indicating that there is a high degree of continuity of community structure. Table V shows the same values calculated for treatment versus control streams at each sampling date. Here again the values for CC exceed 50 and the values for PS_C exceed 30. The poorest fit for these data resulted from a flush of an Ephemerella species in April, 1984, which numerically dominated the EPT numbers for that date, causing low PS_C values for calculations including that data. Table VI lists all the genera of EPT taxa for both watersheds at each date, and provides an enumeration of the numbers of individuals in each genus. Taxa from the "shredder" functional group might be at greater risk from persistent residues on leaves which enter the stream, and among this group those which are active feeders in the fall (spring emerging), when sprayed foliage would be entering the streams could be at greatest risk (Cummins, personal communication). Peltoperla, a genus which fits these criteria, represented a major component of both streams. Examination of numbers and sizes of individuals in the March,1987 sample from Watershed 1 do not suggest that this shredder population has been reduced. Leuctra, another shredder genus was also abundant throughout the sampling period.

Colonization rates on the artificial substrate samplers were too low to allow meaningful analysis of data from them.

During the Parsons study, a survey of terrestrial and aquatic salamanders on the two watersheds was conducted by Dr. Thomas K. Pauley (now at Marshall University, Huntington, WV). His report, which is included as an appendix to this report, suggested that there was some reduction in growth rates for some terrestrial salamander species. Given the short time of his study, he was unable to say what the consequence this might be.

Conclusions:

Dimilin reaches the stream channel during aerial application and as a result of wash-off from the foliage for several subsequent rainfall events. Levels have been measured which exceed the published acute (1.0-1.8 PPB) and chronic (60 PPT) toxicity doses for intolerant taxa. However, the residence time for Dimilin in these high gradient headwater streams is very short. The data on aquatic invertebrate populations indicate that, either as a result of the short residence time or low concentrations, toxic effects were not evident. Dimilin levels on the litter were very persistent, with PPM levels still present after 5 months, and this persistence may be indirectly related to the decline in terrestrial salamamder growth rates seen in the summer survey of Watershed 1 on the Fernow.

Recommendations for Additional Research:

(1) A more definitive study of persistence of Dimilin on forest litter; both in situ, and its potential for persisting on litter reaching the stream.

(2) A study specifically designed to examine the effects of Dimilin contaminated leaves on the shredder functional group in streams.

(3) A study of Dimilin persistence and effects on Piedmont and Coastal streams where the aquatic community includes a larger component of Crustaceans, an intolerant group not well represented in this study.

(4) An examination of the potential for off-site movement of Dimilin residues in stormflow, where more than one or two tributary streams have been over-sprayed.

(5) A study of residues and persistence of Dimilin on non-leaf surfaces of trees resulting from the early application now being considered.

TABLE I

DIMILIN DEPOSITS IN PETRI DISHES ALONG STREAM CHANNELS

SITE	ng/cm^2 (g/h)	PERCENT OF THEORETICAL APPLIED DOSE
WS-1 FERNOW		
WEIRWALL (open canopy)	19.0	28.0[a]
SITE 1 (closed canopy)	1.5	2.3
SITE 2 (partially open canopy)	16.9	25.0
Block 1 Fires Creek (Leatherwood Branch)		
SITE 1 (closed canopy)	1.4	4.2[b]
SITE 2 (closed canopy)	1.0	3.0
SITE 3 (closed canopy)	0.9	2.7
SITE 4 (open canopy)	16.6	49.0
SITE 5 (closed canopy)	1.5	4.5
SITE 6 (wildlife clearing)	19.3	52.7
Block 6 Fires Creek (Bob's Branch)		
SITE 1 (open canopy)	1.1	3.3
SITE 2 (open canopy)	4.9	14.7
SITE 3 (open canopy)	3.3	9.8
SITE 4 (open canopy)	1.8	5.4
SITE 5 (Rhododendron cover)	<0.5	<1.0
SITE 6 (open canopy)	8.9	26.4

a. Theoretical spray dose: 0.06 lb/ac x 454 (g/lb)
= 27.24 g/ac x 2.47 ac/h
= 67.28 g/h

b. Theoretical spray dose: 0.03 lb/ac x 454 (g/lb)
= 13.62 g/ac x 2.47 ac/h
= 33.64 g/h

TABLE II

DIMILIN RESIDUES IN SEDIMENT AND LITTER

Sample	1 hr	1 wk	4 wk	5 mo
SEDIMENT[a]				
S-1	≤ 2.5 PPB	N.D.		
S-2	≤ 2.5 PPB	N.D.		
S-3	4.8 PPB	N.D.		
S-4	4.0 PPB	N.D.		
S-5	10.4 PPB	N.D.		
LITTER[b]				
TF-2	1.4 PPM	1.8 PPM	0.8 PPM	1.7 PPM
TF-4	≤0.5 PPM	0.8 PPM	≤0.5 PPM	≤0.5 PPM
TF-6	N.D.	--	≤0.5 PPM	≤0.5 PPM
TF-7	0.7 PPM	2.2 PPM	1.6 PPM	3.6 PPM
TF-8	1.6 PPM	1.0 PPM	3.6 PPM	N.D.

[a] Minimum detectable amount = 2.5 PPB

[b] Minimum detectable amount = 500 PPB

TABLE III

TAXA RICHNESS VALUES FOR WS-1 (TREATMENT) AND WS-4 (CONTROL) STREAMS ON THE FERNOW

	Pre-spray								Post-spray							
	May 1983		April 1984		March 1986		May 1986		June 1986		July 1986		October 1986		March 1987	
	WS-1	WS-4	WS-1	WS-4	WS-1	WS-4	WS-1	WS-4	WS-1	WS-4	WS-1	WS-4	WS-1	WS-4	WS-1	WS-4
EPHEMEROPTERA (E)	10	8	8	11	4	6	6	7	6	9	5	4	4	5	7	9
PLECOPTERA (P)	9	7	8	10	9	8	8	7	6	9	6	4	6	5	7	8
TRICHOPTERA (T)	7	6	6	10	6	7	5	4	5	6	3	3	5	5	7	8
ODONATA	1	1	1	2	-	1	1	1	1	1	1	2	1	1	1	2
MEGALOPTERA	-	-	1	1	-	1	-	1	-	-	-	-	-	2	-	2
COLEOPTERA	2	2	6	3	2	1	4	1	4	2	2	2	-	2	3	7
DIPTERA	5	3	10	11	7	7	5	7	5	10	5	5	5	6	8	13
OLIGOCHAETA	-	-	1	1	1	-	1	1	1	1	1	-	1	1	1	1
OTHER	8	5	7	3	1	1	2	1	2	2	4	2	4	7	4	7
[G]EPT RICHNESS	26	21	22	31	19	21	19	18	17	24	14	11	15	15	21	25
[G]EPT DENSITY[1]	205	162	195	212	93	111	108	123	117	149	115	73	91	92	192	213
TAXA RICHNESS	42	32	48	52	30	32	32	30	30	40	27	22	26	34	38	57

[1] Abundant = 10, Common = 3, Rare = 1, Summed for all EPT taxa

TABLE IV

Within-Stream Community Similarity

Sample Dates	CC[a] WS-1	CC[a] WS-4	PS_c[b] WS-1	PS_c[b] WS-4
May 1983, May 1986	55	56	61	38
April 1984, March 1986	64	62	35	27
April 1984, May 1986	86	58	51	29
April 1984, March 1987	70	73	79	47
March 1986, March 1987	60	77	34	56
May 1986, June 1986	64	68	70	73

a. $$CC = \frac{C}{(a+b)-C} \times 100$$

where a = number of EPT genera in sample a, b = number of EPT genera in sample b, and c = number of EPT genera in both.

b. $$PS_c = 100-0.5 \sum | a_i - b_i |$$

where a_i = % genus i in sample a

and b_i = % genus i in sample b

TABLE V

Community Similarities between Treatment and Control Streams

	Pre-spray				Post-spray			
	May 1983	April 1984	March 1986	May 1986	June 1986	July 1986	October 1986	March 1987
CC	74	71	52	54	71	53	67	70
PS_c	70	50	32	56	63	72	71	75

TABLE VI
EPT TAXA FROM THE FERNOW
1 = TREATMENT 4 = CONTROL

	PRE - SPRAY								POST - SPRAY							
SSIFICATION	5 May 83		25 Apr 84		5 Mar 86		19 May 8		2 Jun 86		9 Jul 86		7 Oct 86		5 Mar 87	
	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1	4
EMEROPTERA																
tis	20	7	20	3			176	128	118	233	5	11				
ygmula	40	107	76	214	27				1	1					33	58
orus	91	13	65	160		7	59	8	56	11	23				61	40
nacron	2			9												9
nonema	8	8	2	43	1	19	1	18		20		14	33	43	25	31
crocuta	17	19	17	21			1	21	3	82	2	15	13	5	15	37
eletus	15	13	98	67	371	317	25	108	89	52	5		1	6	107	197
raleptophlebia	62	48	44	131	1	1	12		87	18	44	8	1	4	55	67
hemerella	15	57	27	1662		1		3		4					137	162
rylophella				2		2		1		1				9		9
unella	1			2												
ECOPTERA																
phinemoura	118	153	75	246		8	39	25	32	104		3			35	142
trocerca			12	1	9	7	2									1
yedinia	11															
moura				1												
llocapnia						9										
racapnia																69
euctra	81	45	307	327	5	112	43	176	48	169	67	27	31	37	187	463
ealeuctra					1											
eltoperla	297	183	145	97	42	335	136	84	131	165	179	94	170	287	260	417
llonarcys	5															
teronarcys	20	1	38	55	1		1				1		2		13	
soperla	17	9	8	77	4	25	3	11	21	15	2		31	59	18	54
emenus				9				1		5						
ugus	20	52	36	109	71	57	30	20	5	12	19	11	18	15	78	116
lioperla										1						
astaperla	13	1			1											
weltsa			32	24	1	8	1	9	16	7	8		40	8	39	25
Alloperla										1						
TRICHOPTERA																
Wormaldia	4	19	16	38	8	3		1	9	1			5			126
Dolophilodes	30	12											6	10		
Rhyacophila	13	42	21	70	12	41	6	21	18	17		5	2	43	49	230
Diplectrona	68	64	47	93	4	16	9	10	3	9	1	3	39	7	72	98
Aphropsyche					1						1					
Parapsyche				4		9		1						7	1	20
Ceratopsyche									1						1	
Pycnopsyche			13	4	2	5	3			1					25	13
Neophylax	4		2	25	26	7	2								76	6
Psychoglypha		1														
Polycentropus				2		1				1			2			16
Lepidostoma	22	10	18	18			21		3	34	2	1			13	
Lype	2			1										1		7
Paleagapetus				1												
TOTAL	996	864	1119	3516	588	990	570	646	641	964	359	192	394	541	1300	2413

FIGURE I

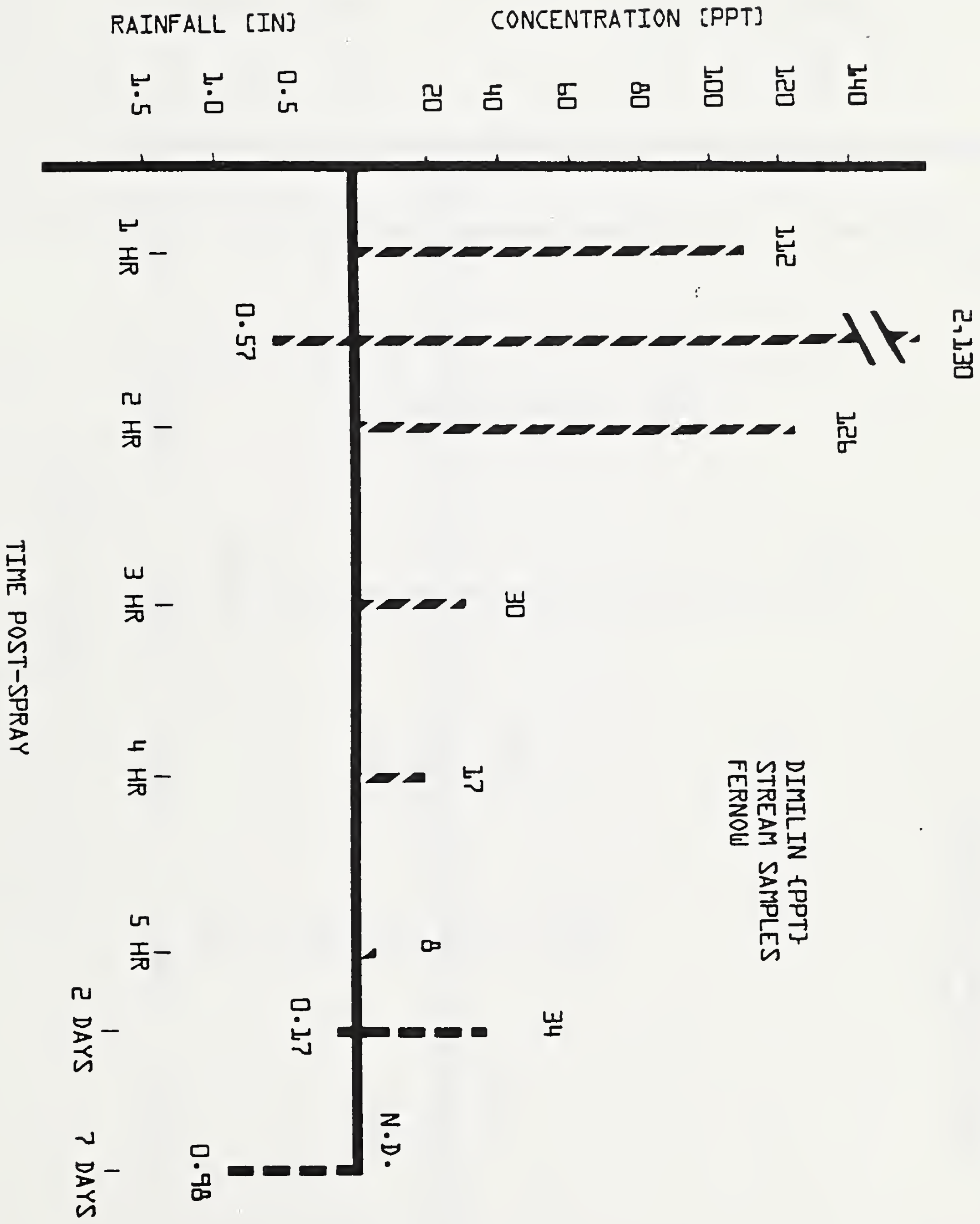

RAINFALL (IN)
CONCENTRATION (PPT)
1.5
1.0
0.5
20
40
60
80
100
120
140
1 HR
2 HR
3 HR
4 HR
5 HR
2 DAYS
7 DAYS
112
2,130
126
30
17
8
34
N.D.
0.57
0.17
0.98
DIMILIN (PPT)
STREAM SAMPLES
FERNOW
TIME POST-SPRAY

FIGURE II

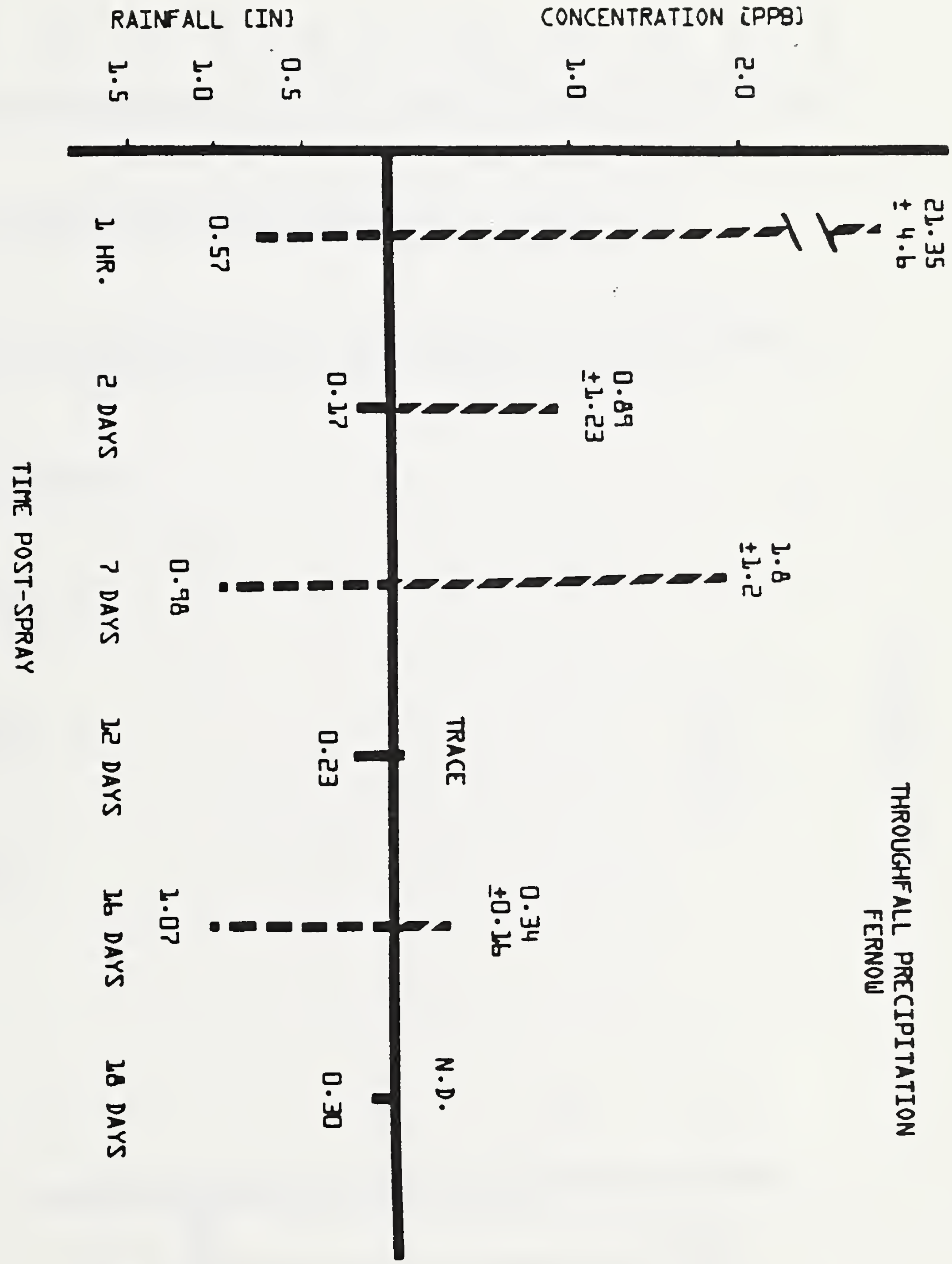
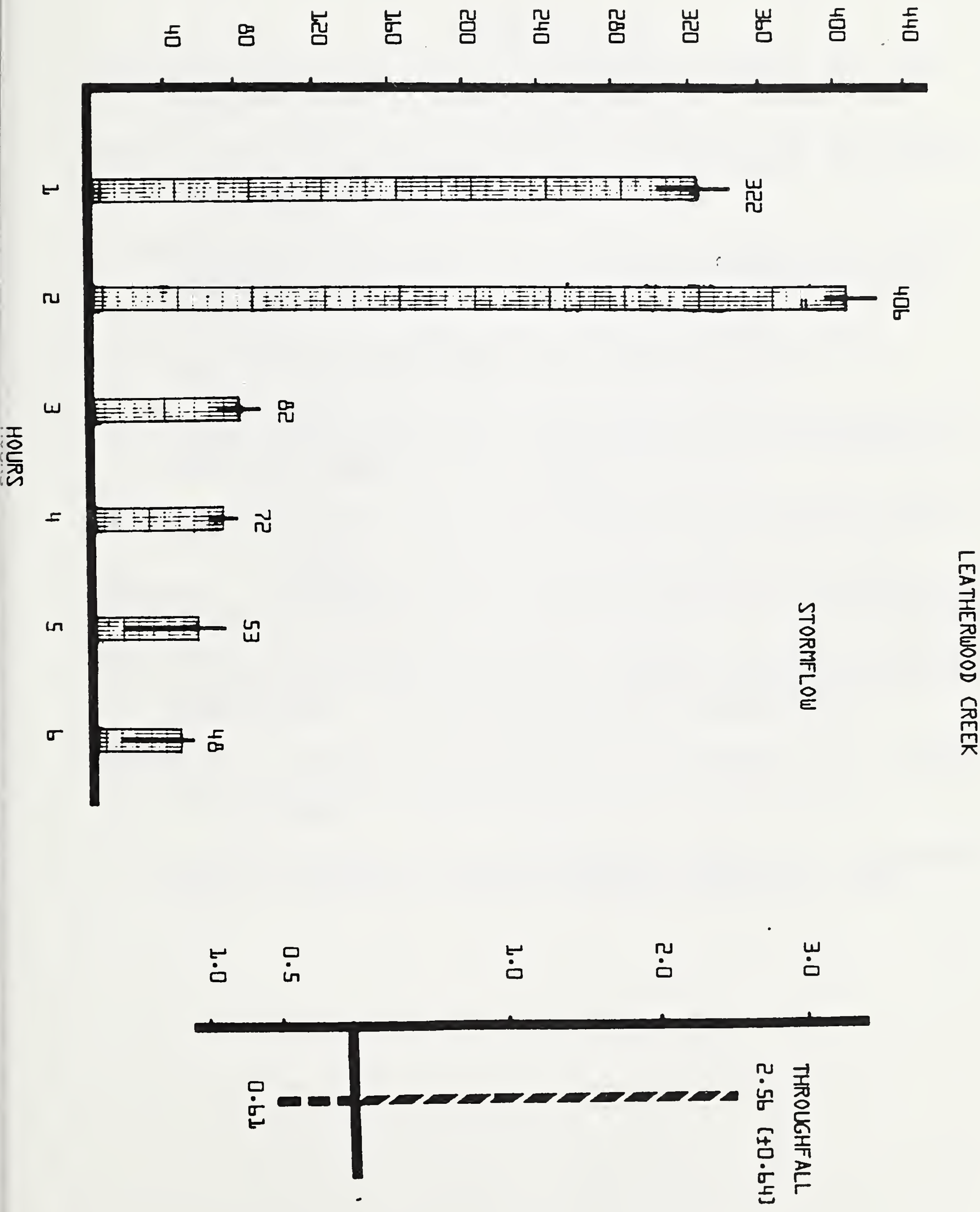

THROUGHFALL PRECIPITATION
FERNOW
CONCENTRATION (PPB)
RAINFALL (IN)
2.0
1.0
0.5
1.0
1.5
21.35
± 4.6
0.57
1 HR.
0.89
±1.23
0.17
2 DAYS
1.8
±1.2
0.98
7 DAYS
TRACE
0.23
12 DAYS
0.34
±0.16
1.07
16 DAYS
N.D.
0.30
18 DAYS
TIME POST-SPRAY

FIGURE III

DIMILIN CONCENTRATION (PPT)



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Actual Costs: NAPIAP	1986	1987
Salaries and fringe benefits		
GS-6 Biological Lab. Tech.	12,930.00	12,930.00
Supplies and Materials		
Sample collection	7,000.00	3,000.00
Residue Analysis	4,480.00	1,352.00
Invertebrate Studies	2,000.00	500.00
Travel/Vehicle mileage	2,950.00	2,950.00
ADP	100.00	200.00
Total Direct Costs:	29,460.00	20,932.00
Overhead (10 %)	2,946.00	2,068.00
TOTAL	32,408.00	23,000.00

Duphar,B.V.

Aerial application costs	3,000.00